Supplementary Material

Table S1. Removal percentage of pharmaceutical compounds using AOPs.

Pharmaceutical	Type	AOP type	Experimental conditions	Removal %	Observations	Reference
Ciprofloxacin (CIP)	Antibiotic	O_3-based AOPs	O_3 flow rate of 120 mL min^{-1} $[Cip]_0$ = 7.5–45 mg L^{-1} pH 3–10 (buffer) *T* = 6–62 °C [*t*-BuOH] = 30 mM	95	By HPLC-MS analysis, the desethylene ciprofloxacin was identified as one of the degradation products. A strong pH dependence of the formation of desethylene ciprofloxacin was observed.	[78]
Ciprofloxacin	Antibiotic	O_3-based AOPs	Laboratory scale $[O_3]$ = 0.23 mM; pH = 7.8–8.7 $[C]_o$ = 572 ng L^{-1}	98 ≈15 (TOC)	18 filtered wastewaters were characterised: 10 domestic and 8 urban. Subproducts: carboxylates and low molecular weight oxalates	[59]
		O_3/H_2O_2	Laboratory scale $[O_3]$ = 0.23 mM $[C]_o$ = 741 ng L^{-1} $[H_2O_2]$ = 20 mM, 0.15 mL (30% w/v) every 5 min in 5 L	>93 >90 (TOC)		
Ciprofloxacin	Antibiotic	UV/H_2O_2	LP-Hg lamp $[C]_0$ = 5 μM Toxicity assay with *vibrio fischeri* bacteria Types of water: treated water, ultrapure, surface and wastewater	Total or not detected in the effluent after 11 448 mJ cm^{-2}	The treated water was more rapidly degraded. Toxicity increased and then decreased	[58]
Ciprofloxacin	Antibiotic	UV/H_2O_2	LP-Hg lamp pH natural T = 20 ºC	Total or not detected in the effluent (20 min)	Laboratory scale Real wastewater	[57]

			$[C]_0$= 22,30 μg L^{-1} $[C]_0$= 17,7 μg L^{-1} $[C]_0$= 98,53 μg L^{-1} $[H_2O_2]$ = 25 mg L^{-1} $[H_2O_2]$ = 50 mg L^{-1} $[H_2O_2]$ = 100 mg L^{-1}		For each ciprofloxacin concentration, three UV/H_2O_2 tests with different H_2O_2 concentrations	
Ciprofloxacin	Antibiotic	UV/H_2O_2	UV-C irradiation (λ = 254 nm, 230 W) Q_{UV} = 0.9 kJ L^{-1} $[H_2O_2]$ = 5 mg L^{-1} 80 L of CAS effluents spiked with CIP (100 μg L^{-1}) pH: inherent, 7.5–8.0	>99% (90 min)	Pilot-scale setup	[50]
		$Sunlight/H_2O_2$	Natural solar irradiation Q_{UV} = 8 kJ L^{-1} $[H_2O_2]$ = 30 mg L^{-1} 60 L of CAS effluents spiked with CIP (100 μg L^{-1}) pH: inherent, 7.5–8.0	>99% (60 min)		
Ciprofloxacin	Antibiotic	UV/H_2O_2	T = 20 ºC Monochromatic Pen-Ray Hg lamp (254 nm; 4750 μW cm^{-2})	Total or not detected in the effluent (90 min) 28 (TOC)	Under mechanical stirring and temperature of 20ºC, a constant current density of 50 mA cm^{-2} was applied during the 90 min of electrolysis.	[79]
		$UV/H_2O_2/Fe^{2+}$	T = 20 ºC Monochromatic Pen-Ray Hg lamp (254 nm; 4750 μW cm^{-2}) 0,10 mmol $FeSO_4 \cdot 7H_2O$	Total or not detected in the effluent (90 min) 54,8 TOC (90 min)		

				84,6 TOC (360 min)		
Amoxicillin	Antibiotic	UV/H_2O_2	Low pressure Hg arc-UV lamp I = 8 × 10^{-7} Eintein L^{-1} s^{-1} *T* = 20 °C [H_2O_2] = 0.4–10 mM Antibacterial activity was measured using *Escherichia coli* bacteria	99% (20 min)	Pseudo-first order kinetics Low mineralization UV/H_2O_2 process effectively eliminated antibacterial activity	[64]
Amoxicillin	Antibiotic	UV/TiO_2	[C]$_o$ = 104, 105, and 103 mg L^{-1} respectively pH = 5 DOC = 8.4 mg L^{-1} TiO_2 (Anatase > 99%) UV(365 nm)	20%	Pseudo-first order kinetics k = 0.007, 0.003 and 0.029 min^{-1}, respectively At pH 11 was achieved the highest degradation.	[65]
		UV/H_2O_2/TiO_2		≈ Total or not detected in the effluent		
Clarithromycin	Antibiotic	O_3-based AOPs	[C]$_o$ = 1 × 10^4 M [O_3] ≈ 10^{-5} M pH (phosphate buffer) k_{O3} = 7 × 10^4 M^{-1} s^{-1} (pH 7)	Total or not detected in the effluent	Ultrapure water Subproduct determination Toxicity test with *P. putida*	[80]
Diclofenac	Anti-inflammatory	O_3-based AOPs	[C]$_o$ = 26 μM (8 mg L^{-1}) Molar ratio: (O_3: diclofenac) 10:1. With and without *t*-BuOH; [O_3]$_o$ minimum for 10 μg L^{-1} of diclofenac = 0.016 mg L^{-1} k_{O3} = 6.8 × 10^5 M^{-1} s^{-1}	Total or not detected in the effluent (complete degradation of potentially toxic primary products)	Laboratory scale Subproducts: diclofenac-2,5-iminoquinone (32%), 5-hydroxydiclofenac (7%), 2,6-dichloroaniline (19%)	[74]
Diclofenac	Anti-inflammatory	UV/H_2O_2	LP and MP lamp UV doses ranged from 300–700 mJ cm^{-2} [H_2O_2] = 0–10 mg L^{-1}	>80%	Removal was largely attributed to direct photodegradation	[61]
Sulfamethoxazole	Antibiotics	O_3-based AOPs	*T* = 22 °C pH_{SMX} = 4.63 [SMX]$_0$ = 30 mg L^{-1}	99,9	Ozone primarily reacts with SMX by attacking the aniline (p-sulfonylaniline) moiety	[63]

Sulfamethoxazole	Antibiotics	UV/H_2O_2	LP and MP lamp UV doses ranged from 300–700 mJ cm^{-2} $[H_2O_2]$ = 0–10 mg L^{-1}	>90%	Removal was largely attributed to direct photodegradation	[61]
Sulfamethoxazole	Antibiotics	UV/H_2O_2	LP-Hg lamp (10W, 254 nm) pH= 3 – 8. $[SMX]_0$ = 20 μM; $[H_2O_2]_0$ = 1 mM;	Total or not detected in the effluent (60 min)	Filtrated waters from two drinking water plants using surface water and ground water as water sources	[62]
Sulfamethoxazole	Antibiotic	UV/H_2O_2	UV-C irradiation (λ = 254 nm, 230 W) Q_{UV} = 0.9 kJ L^{-1} $[H_2O_2]$ = 5 mg L^{-1} 80 L of CAS effluents spiked with CIP (100 μg L^{-1}) pH: inherent, 7.5–8.0	>99% (90 min)	Pilot-scale setup	[50]
		Sunlight/H_2O_2	Natural solar irradiation Q_{UV} = 42 kJ L^{-1} $[H_2O_2]$ = 30 mg L^{-1} 60 L of CAS effluents spiked with CIP (100 μg L^{-1}) pH: inherent, 7.5–8.0	~46% (300 min)		
Sulfamethizole	Antibiotic	O_3-based AOPs	O_3 flow rate of 1.2 L min^{-1} $[O_3]_0$ = 1–3.2 mg L^{-1} $[S]_0$ = 1000 μg L^{-1} $[HCO_3^-]$ = 2–20 mM T = 22 °C pH = 2–10	99,9		[81]
Ibuprofen	Anti-inflammatory	UV/H_2O_2	pH natural T = 20 ºC $[C]_0$= 54.60 μg L^{-1}	89,8 – 100 (40 min)	Laboratory scale Real wastewater	[57]

			$[C]_0$= 69.60 μg L^{-1} $[C]_0$= 275.00 μg L^{-1} $[H_2O_2]$ = 25 mg L^{-1} $[H_2O_2]$ = 50 mg L^{-1} $[H_2O_2]$ = 100 mg L^{-1}		For each ibuprofen concentration, three UV/H_2O_2 tests with different H_2O_2 concentrations	
Naproxen	Anti-inflammatory	O_3-based AOPs	$[O_3]$ = 0.23 mM; pH = 7.8–8.7 $[C]_o$ = 334 ng L^{-1}	>93 ≈15 (TOC)	Laboratory scale 18 filtered wastewaters were characterised: 10 domestic and 8 urban. Subproducts: carboxylates and low molecular weight oxalates	[59]
		O_3/H_2O_2	$[O_3]$ = 0.23 mM $[C]_o$ = 389 ng L^{-1} $[H_2O_2]$ = 20 mM, 0.15 mL (30% w/v) every 5 min in 5 L	>94 >90 (TOC)		
Carbamazepine	Antiepileptic	UV/H_2O_2	LP-Hg lamp (83 W, 1,04 W/cm^2, 254 nm) $[C]_0$=5 mg/L $[H_2O_2]$ = 0,2 g/L	95 (30 min) 99,7 (60 min)	Laboratory scale	[69]
Carbamazepine	Antiepileptic	UV/H_2O_2	LP-Hg lamp pH natural T = 20 ºC $[C]_0$= 59,83 μg L^{-1} $[C]_0$= 95,03 μg L^{-1} $[C]_0$= 281,00 μg L^{-1} $[H_2O_2]$ = 25 mg L^{-1} $[H_2O_2]$ = 50 mg L^{-1} $[H_2O_2]$ = 100 mg L^{-1}	80,1 – 100 (40 min)	Laboratory scale Real wastewater For each carmazepine concentration, three UV/H_2O_2 tests with different H_2O_2 concentrations	[57]
Carbamazepine	Antiepileptic	UV/H_2O_2	LP and MP lamp UV doses ranged from 300–700 mJ cm^{-2} $[H_2O_2]$ = 0–10 mg L^{-1}	<5%	was not appreciably removed with UV/H_2O_2 treatment	[61]
Chlortetracycline	Antibiotic	O_3-based AOPs	$[CTCN]_0$ = 30 mg L^{-1} pH $_{CTCN}$ = 4.33 *T* = 22 °C	99,9		[63]
Lincomycin	Antibiotic	UV/H_2O_2	$[C]_o$ = 0.03 mM LP lamp (254 nm) [*t*-BuOH] = 10 mM	≈ 80 (in 3 min)	No toxic product generation	[68]

			k_{OH} = 4.37 × 10^9 M^{-1} s^{-1} (pH 5.5) k_{OH} = 4.59 × 10^9 M^{-1} s^{-1} (pH 7.5)			
		O_3-based AOPs	$[C]_o$ = 0.5 mM $[O_3]_o$ = 0.4 mM pH = 5.5–7.5 [*t*-BuOH] = 10 mM k_{O3} = 1.53 × 10^5 M^{-1} s^{-1} (pH 3) k_{O3} = 4.93 × 10^5 M^{-1} s^{-1} (pH 6.7) k_{OH} = 4.37 × 10^9 M^{-1} s^{-1} (pH 5.5) k_{OH} = 4.59 × 10^9 M^{-1} s^{-1} (pH 7.5)	Total or not detected in the effluent (in 2 min) <10 (TOC in 180 min)	without toxicity in 1 h and regardless of pH	
Levofloxacin	Antibiotic	O_3-based AOPs	$[O_3]_0$ = 2500 ppm_v $[L]_0$ = 16.4 mg L^{-1} *T* = 27.5 °C pH 3–7 (Buffer) [*t*-BuOH] = 30 mM $[H_2O_2]$ = 2–100 μM	99,9	Degradation was about 2 times faster at pH 10 compared to pH 3 and 7	[60]
Metronidazole	Antibiotic	UV/H_2O_2	$[C]_o$ = 6.0 μM (1 mg L^{-1}) pH 6.0 LP lamp 254 nm (1.5 mW cm^{-2}); $[H_2O_2]$ = 25 mg L^{-1}	59	Degradation exhibited pseudo-first order reaction kinetics	[67]
			$[C]_o$ = 6.0 μM (1 mg L^{-1}) pH 6.0 LP lamp 254 nm (1.5 mW cm^{-2}); $[H_2O_2]$ = 50 mg L^{-1}	67		
			$[C]_o$ = 6.0 μM (1 mg L^{-1}) pH 6.0 MP lamp 200–400 nm (1.9 mW cm^{-2}) $[H_2O_2]$ = 25 mg L^{-1}	58		
			$[C]_o$ = 6.0 μM (1 mg L^{-1}) pH 6.0 MP lamp 200–400 nm (1.9 mW cm^{-2}) $[H_2O_2]$ = 50 mg L^{-1}	64		
Metronidazole	Antibiotic	H_2O_2/Fe^{2+}	$[C]_o$ = 6.0 μM (1 mg L^{-1}) $[Fe^{2+}]$ = 2,94 μM	53	The degradation kinetics followed a second order	[67]

			$[H_2O_2]$ = 29,4 μM pH 3.5		Adding more ferrous ions enhanced the oxidation rate	
			$[C]_o$ = 6.0 μM (1 mg L^{-1}) $[Fe^{2+}]$ = 5,88 μM $[H_2O_2]$ = 29,4 μM pH 3.5	73		
			$[C]_o$ = 6.0 μM (1 mg L^{-1}) $[Fe^{2+}]$ = 11,76 μM $[H_2O_2]$ = 29,4 μM pH 3.5	76		
		$UV/H_2O_2/Fe^{2+}$	$[C]_o$ = 6.0 μM (1 mg L^{-1}) $[Fe^{2+}]$ = 2,94 μM $[H_2O_2]$ = 29,4 μM pH 3.5	74		
			$[C]_o$ = 6.0 μM (1 mg L^{-1}) $[Fe^{2+}]$ = 5,88 μM $[H_2O_2]$ = 29,4 μM pH 3.5	91		
			$[C]_o$ = 6.0 μM (1 mg L^{-1}) $[Fe^{2+}]$ = 11,76 μM $[H_2O_2]$ = 29,4 μM pH 3.5	94		
Metronidazole	Antibiotic	O_3-based AOPs	$[O_3]$ = 0.23 mM; pH = 7.8–8.7 $[C]_o$ = 188 ng L^{-1}	91 ≈15 (TOC)	Laboratory scale 18 filtered wastewaters were characterised: 10 domestic and 8 urban. Subproducts: carboxylates and low molecular weight oxalates	[59]
		O_3/H_2O_2	$[O_3]$ = 0.23 mM $[C]_o$ = 212 ng L^{-1} $[H_2O_2]$ = 20 mM, 0.15 mL (30% w/v) every 5 min in 5 L	92 >90 (TOC)		
Ketoprofen	Anti-inflammatory	O_3-based AOPs	$[O_3]$ = 0.23 mM; pH = 7.8–8.7 $[C]_o$ = 335 ng L^{-1}	69 ≈15 (TOC)	Laboratory scale 18 filtered wastewaters were characterised: 10 domestic and 8 urban.	[59]
		O_3/H_2O_2	$[O_3]$ = 0.23 mM $[C]_o$ = 346 ng L^{-1}	70 >90 (TOC)		

			$[H_2O_2]$ = 20 mM, 0.15 mL (30% w/v) every 5 min in 5L		Subproducts: carboxylates and low molecular weight oxalates	
Oxytetracycline	Antibiotic	UV/H_2O_2	LP-Hg lamp $[C]_0$ = 5 μM Toxicity assay with *vibrio fischeri* bacteria Types of water: ultrapure, treated water, surface and wastewater	Total or not detected in the effluent after 11 448 mJ cm^{-2}	The treated water was more rapidly degraded. Toxicity increased and then decreased	[58]
Doxycycline	Antibiotic	UV/H_2O_2	LP-Hg lamp $[C]_0$ = 5 μM Toxicity assay with *vibrio fischeri* bacteria Types of water: ultrapure, treated water, surface and wastewater	Total or not detected in the effluent after 11 448 mJ cm^{-2}	The treated water was more rapidly degraded. Toxicity increased and then decreased	[58]
Gemfibrozil	Lipid-lowering drug, lipid regulator	O_3-based AOPs	$[O_3]$ = 0.23 mM; pH = 7.8–8.7 $[C]_o$ = 618 ng L^{-1}	>99 ≈15 (TOC)	Laboratory scale 18 filtered wastewaters were characterised: 10 domestic and 8 urban. Subproducts: carboxylates and low molecular weight oxalates	[59]
		O_3/H_2O_2	$[O_3]$ = 0.23 mM $[C]_o$ = 608 ng L^{-1} $[H_2O_2]$ = 20 mM, 0.15 mL (30% w/v) every 5 min in 5L	>99 >90 (TOC)		
Bezafibrate	Lipid-lowering drugs, lipid regulator	O_3-based AOPs	$[O_3]$ = 0.23 mM; pH 7.8–8.7 $[C]_o$ = 126 ng L^{-1}	≈94 ≈15 (TOC)	Laboratory scale 18 filtered wastewaters were characterised: 10 domestic and 8 urban. Subproducts: carboxylates and low molecular weight oxalates	[59]
Sulfadiazine, Sulfamethizole, Sulfathiazole	Antibiotic	O_3-based AOPs	O_3 flow rate of 1.2 L min^{-1} $[O_3]_0$ = 1–3.2 mg L^{-1} $[S]_0$ = 1000 μg L^{-1} [HCO3-] = 2–20 mM *T* = 22 °C	99,9	It exhibited moderate reactivity to ozone	[81]

			pH = 2–10 k_{O3} > 2 × 10^4 M^{-1} s^{-1} at pH of 2			
Mefenamic acid	Anti inflammatories	O_3-based AOPs	[MEF]$_0$ = 0.54 mg L^{-1} pH = 4–9 (buffer) T = 25 °C [O_3]$_0$ = 0.7 mg L^{-1}	pH 4 = 37.5 pH 7 = 42.5 pH 9 = 45.8	Degradation occurred during the first 5 min of treatment The degree of mineralization was limited: at pH 9 only 25% of Mefenamic acid was mineralized.	[82]